E-interview with Dr. Okabe

Spatial Analysis — Present and Future

Jungyeop Shin ('Shin'): First of all, I appreciate you having this e-interview for members of the Korean GIS research group. This discussion with you will be a great help in understanding current paradigms within the field of fundamental spatial analysis and statistics. Although there have been a number of international researchers developing approaches and methodologies of spatial analysis and statistics, there are only a few scholars of spatial analysis in the Asian region. Your work has greatly contributed to the global development of spatial analysis. Would you please let us know your academic background for this?

Okabe: As you know, a quantitative revolution in geography occurred in the 1950s in the USA. In the 1970s, when I graduated from the University of Tokyo, quantitative spatial or location analysis was still advancing in the USA. Because I wanted to understand this better, in 1972 I moved to the Department of City and Regional Planning at Berkeley at the University of California, where William Alonso, who was a pioneer of location theory, was teaching.

At that time the university was still seething from anti-Vietnam war sentiment, and the classes provided by the department were rather policy oriented. Few of them dealt with quantitative spatial analysis. One day Bill Alonso gave me a discussion paper written by Tony Smith. This discussed the rigorous formulation of a cell count method. I was very much attracted to this, and I decided to move to the Department of Regional Science at the University of Pennsylvania, where Tony was teaching. The classes there were very stimulating; in particular, Tony's teaching of spatial statistics was excellent and fascinated me. Tony asked students to write a term paper, and I wrote an article on spatial autocorrelation. This I developed into my debut publication, "A Note on Geary's Spatial Contiguity Ratio", in *Geographical Analysis* 1976. I also wrote my PhD thesis, which dealt with the stochastic spatial interaction models, under Tony's supervision (Okabe, 1976b).

After I completed my PhD I came back to Japan to find a job. This might sound strange today, but at that time, a PhD obtained in the USA was not always valued at home. So I had to write the second thesis for the Department of Urban Engineering in the University of Tokyo. This dealt with city size distribution. Specifically, I analyzed the theoretical relationship between the Pareto distribution of city size and the rank-size rule using order statistics, and I developed a new rule: [city size]×[its rank – 1] = constant in place of the old one [city size]×[its rank] = constant (see Okabe, 1979). I like this new rule, but unfortunately it is not widely known.

After the second thesis, I got a position in the Institute of Socio-Economic Planning at the University of Tsukuba. Since then, I have been studying and enjoying spatial analysis.

Shin: One of your distinguished efforts was to establish the CSIS, the Center for Spatial Information Science, in Japan, which is one of the academic hubs for researching the issues of spatial analysis and statistics. Only a few such centers exist for GIS and spatial analysis in the world. In the US I think of the NCGIA—the National Center for Geographical Information and Analysis at the University of California in Santa Barbara; there's the State University of New York at Buffalo, and the University of Maine. In the UK there's CASA, the Centre for Advanced Spatial Analysis. It would not have been easy to establish such a GIS R and D center in Asia, where the academic environment was not yet so integrated. How did you introduce the CSIS to Japan?

Okabe: In 1988 I visited the University of California at Santa Barbara for a week and met Mike Goodchild. By coincidence, it was the week for the opening symposium of the NCGIA. This event made me understand the importance of systematic studies in geographical information science. I came to believe that spatial analysis would be enhanced by geographic information systems or GIS, as they are now generally called.

After one year at the University of Pennsylvania as a visiting scholar, I came back to Japan and learned that the Science Council of Japan had recommended establishment of the National Center for Cartography in 1988. I joined in the movement to establish the center, but we had many difficulties. After many twists and turns, the CSIS—the Center for Spatial Information Science—came into being at the University of Tokyo in 1998, and I became director. It took 10 years! However, this was only half the task. The center was not a national one, but was an intra center of the University of Tokyo, although it served researchers outside the university. It took an additional eight years for it to become a national research organization. Fortunately, this year, it became the National CSIS. We will celebrate the establishment in this fall under its new young director, Ryosuke Shibasaki.

The center consists of four divisions. They are spatial information analysis, spatial information integration, spatiotemporal socioeconomic research, and spatial information infrastructure. The staff of the center is carrying out studies with colleagues in Japan and abroad. Collaboration with similar world organizations, especially those in Asia is being sought. I know that Korea has these facilities, and I hope that we can soon begin cooperation.

Shin: One of the central parts in your research is the Voronoi diagram, which opened up a new way of modeling the geometric world and implementing faster and more efficient data processing. By applying the Voronoi approach, much quantitative research in the field of spatial analysis and statistics based on geometric and statistical algorithms has helped us explore principles and organization efficiently. With its abundant algorithms and approaches, your famous book, *Spatial Tessellations: Concepts and Applications of Voronoi Diagrams* made the Voronoi approach central to spatial analysis and statistics. What was your motivation to study Voronoi diagrams?

Okabe: As is well known, the Voronoi diagram gives a first approximation for market areas such that, if consumers use their nearest neighborhood stores, the sales areas are given by the polygons of the Voronoi diagram generated by them. Together with Atsuo Suzuki, I first applied the Voronoi diagram to the Hotelling spatial competition model. That model assumed a one-dimensional space, but our model assumed a two-dimensional space where competitive market areas are given by Voronoi polygons. Urban and regional economists tended to believe that results obtained in one dimension would also hold in two-dimensional space. I doubted this assumption. We actually showed this expectation was false (Okabe and Suzuki, 1987). Interestingly enough, not only spatial economists but also researchers in OR, political science, and animal ecology paid attention to our results. I noticed from this interest that the Voronoi diagram would attract researchers in wider fields.

In this regard I received a message from Barry Boots, who was proposing to write a book on the Voronoi diagram. I knew him by his outstanding papers but we had not corresponded with each other before this contact. Through exchanging e-mails, I noticed we both loved the Voronoi diagram because it was a very simple concept, yet could be extended in hundreds of ways, and provided powerful concepts for the understanding of spatial phenomena. Moreover, we appreciated the Voronoi diagram's artistic beauty! 'Voronoi Art' has actually since appeared. (http://voronoi.hanyang.ac.kr/vd2005/ Voronoi_Art/Index.html).

Together we wrote a book proposal for consideration in the John Wiley series of Probability and Statistics. Very fortunately the world-renowned statistician David Kendall liked our proposal and we began to develop the book in 1988. We soon realized our book would be more complete if the computational part was strengthened. So we invited Kokichi Sugihara to be the third coauthor. The book development progressed via e-mail as we saw each other only a few times. After four years of rigorous e-mail discussion, the book entitled *Spatial Tessellations: Concepts and Applications of Voronoi Diagrams* was published in 1992.

Since the book was published, theories and applications of the Voronoi diagram have been rapidly deepened and extended, and hundreds of resultant papers have appeared in the literature of the natural as well as the social sciences. In particular, the probabilistic properties of the Voronoi diagram came to be theoretically possible; they had been examined with Monte Carlo simulations in the first instance. To include new developments, we invited Sung Nok Chiu to be the fourth coauthor and published a second edition of our book in 2000. I am very happy to know that we have been cited in more than 1,000 academic papers by now. I am also pleased that the Voronoi Diagram Research Center of Hanyang University in Korea has been developing theories and applications and the International Symposium on Voronoi Diagrams in Science and Engineering is now held every two years.

Shin: Many methodologies and algorithms in spatial analysis and statistics have contributed to exploration of spatial patterns and processes. Some famous methods are Moran's I, LISA, K-function, Kriging, and so on. Even though they are very powerful tools there are limitations to their broad use and application in the real world. For example, the detailed examination of significant patterns from a linear spatial arrangement usually depends on geometric distribution information. In this respect, in my opinion, your research direction assuming a network space is realistic and is an efficient application to worldly phenomena. Would you please explain your network approach to analysis and statistics?

Okabe: Traditionally, spatial analysis assumed an 'ideal space', that is, a homogeneous plane with Euclidean distance. This assumption was convenient for developing pure theories and for geometrical computation. However, the real world is not represented by an 'ideal space'.

For instance, let us consider the distribution of fast-food providers in urban areas. These shops are located along streets and we access them via a street network. We cannot go straight from our homes to the eateries like a bird. It is therefore more realistic to assume a network space with a shortest-path distance rather than a plane with Euclidean space. This change in assumption asks us to develop new methods for spatial analysis.

In this connection, let me show you two interesting illustrations.

Figure 1: Uniformly random or nonrandom?

Having seen Figure 1, nobody would consider the points are randomly distributed. Nonrandom is true if we assume a plane. However, it becomes false if we assume a network. In fact, the points in Figure 1 are randomly distributed on a network as in Figure 2.

Figure 2: Nonrandom points on a plane but uniformly random points on a network.

These examples are very instructive. If we apply methods of spatial analysis that assume a homogeneous plane with Euclidean distance to the distribution of facilities in urban areas, we will reach a false conclusion. This misleading application motivated me to develop a new class of methods for spatial analysis that assumes a network space with the shortest-path distance. Along with my colleagues I have developed the network K function method (Okabe and Yamada, 2000), the network cell count method, the network nearest distance method, the network kernel method, generalized network Voronoi diagrams and so forth.

Shin: For this purpose, I hear you are also developing a software package for those new methods for practical implementation. Would you tell me the shape of the software use?

Okabe: Yes, with Keiichi Okunuki, Shino Shiode, Totshiaki Satoh, and Kyoko Okano I am developing a toolbox for spatial analysis on a network called SANET. This is a free toolbox for nonprofit users. You can download it from http://okabe.t.u-tokyo.ac.jp/okabelab/atsu/sanet/sanet-index.html
A reason why I am engaged in this development is that in recent years the use of spatial analysis has expanded to various fields, particularly in the humanities and social sciences (Okabe 2005). In addition, users of spatial analysis now include not only academic researchers but also non-academic analysts in other walks of life, such as the managers of retail stores. They need to have a user-friendly toolbox for spatial analysis in the GIS environment. To respond to this demand, we are developing the GIS-based SANET toolbox (Okabe et al., 2006). Version 3 has been released and this will be continuously updated by the research team. I am happy to say that SANET is now used by analysts in 37 countries.

Shin: Lastly, we need to look at the future of spatial analysis and statistics. Although we have had great progress in the research over recent years, we still need to address exploration of efficient application in the real world. Furthermore, we are experiencing new challenges and academic environments such as a higher demand for advanced spatial analysis and its appropriate use in the ubiquitous society that we will mention later. Considering this environment, I would like to ask how you see the future of spatial analysis.

Okabe: I think there are two complementary but differing future directions for spatial analysis. Analogically speaking, a high mountain has a broad foot. If the foot is narrow, the top cannot be high. Spatial analysis becomes rich when spatial analysis at the 'top' is associated with spatial analysis at the 'foot'.

The spatial analysis at the 'foot' means spatial analysis for nonspecialist analysts. As we have mentioned already, today many types of analysts, such as retail managers, government officers, and NPO volunteers, want to carry out spatial analysis. To respond to their demand, we need to develop methods or tools that everyone can easily operate, like word processors. I think that GIS provides a good environment for developing such aids. SANET aims at this type of spatial analysis. I look forward to the days when spatial analysis is enjoyed by everybody in everyday life.

Spatial analysis at the 'top' calls for advanced or sophisticated concepts and approaches. There are many attractive peaks in the mountain range of spatial analysis, but let me focus on three.

Users who are not professional spatial analysts often complain that the space assumed by the analysis is far from actual. For instance, managers of fast-food outlets try to find a maximum-profit site by considering the detail of spatial factors, such as traffic flow in the street front, for example, one-way or two-way; the type and style of adjacent buildings; shop visibility within a street, and so forth. A traditional method is to analyze attribute data aggregated with respect to spatial units, say census tracts, using a regression model. However, such an analysis is too imprecise to exactly locate a profitable site. What is needed is a class of methods that can deal with disaggregated spatial objects together with their detailed attribute values. We call such spatial analysis *object-oriented microspatial analysis*. I think spatial analysis on a network is a first step towards this.

In recent years many detailed spatial data have become available not only with respect to pinpointing locations but also time. For instance, I am now analyzing the competitive impact of a fitness club on existing clubs using two years of daily client data, comprising observations from one year before the opening of the competing club and from one year of its operation. The data include the date when individual members signed up and resigned, where they lived and where they worked, what day and time they visited the club house and what time they left, what fitness machines they used, and so forth. To analyze the impact of a new fitness club on the spatial behavior of users, including the choice of clubs, traditional cross-sectional spatial analysis is insufficient.

The resolution of time data used in the fitness club study is one minute, but division of available time data becomes finer and finer. For instance, I am now studying the spatial interaction behavior of free-range chickens using a WiFi positioning system (Okabe et al., 2006). This provides the location of 18 free-range chickens every second over several days. To analyze such finely detailed spatiotemporal data, we need new concepts of analysis.

A third peak in the mountain range of spatial analysis is rather more distant, but it appears very tall and attractive. We are in the midst of an ongoing revolution brought by information and communication technology (ICT). In the future ICT society, microcomputers, computer tips, tags, and geosensors will be embedded in many things in our environment. Society enriched by such a system is called the *ubiquitous computing society*. We can see a sign of this society now. We are constantly using cell phones everywhere. This trend is especially advanced in the Asian countries. We are on the frontier of the ubiquitous computing society. Don’t you think it is exciting to consider what spatial analysis can be developed to support such a society? It might be called *real-time spatial analysis*.

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